Exact solutions of random vibration responses for rectangular thin plate

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Abstract

Usually, the plate structure is subjected to various excitations such as the earthquakes, winds, waves and turbulent boundary, etc., which commonly present the randomness both in temporal and spatial domain. Random vibration analysis for plate structure involves two types of model. The first is a continuous model based on the high-order partial differential equation, from which the analytical solution of random response may be achieved. The second is a discrete model in which the continuum structure with infinite degrees of freedom is discretized to a multiple degrees of freedom (MDOF) system, via the numerical technique such as the popular finite element method (FEM). The discrete model can be utilized to approximately obtain the stochastic dynamical responses of structure. However, the continuous model can describe accurately its mechanical behavior, and is suitable to achieve the credibly exact solutions of structures for verifying the discrete model and associated numerical methods. This work aims to address the problem that there is a lack of exact solutions of random vibration responses, especially the stress solutions of thin plate.

This paper proposes discrete analytical method to efficiently achieve the exact solutions of stationary and nonstationary stochastic responses for rectangular thin plate. Firstly, the exact solutions of free vibration for thin plate with SSSS, SSSC, SCSC, SFSF, SSSF and SCSF boundary conditions are introduced to random vibration analysis. By using the pseudo excitation method (PEM), the fully analytical power spectral density (PSD) functions of the transverse deflection, velocity and acceleration for thin plate under random base acceleration excitation are derived. Subsequently, the PSD formula of new equivalent von Mises stress containing all cross-correlation terms between stress components is established based on PEM. Moreover, to enhance computational efficiency, the discrete analytical method (DAM) that realizes the discretization for the modal coordinates and frequency domain is developed. For calculating the PSD of time-variant responses such as the transverse deflection, velocity, acceleration and stress components of thin plate under nonstationary excitation, the precise integration technique is adopted to substitute for the Duhamel time integral. Finally, the efficiency of DAM and the accuracy of exact solutions for stochastic responses of rectangular thin plate are scrutinized by comparison with the fully analytical and finite element solutions.

Keywords: random vibration; rectangular thin plate; discrete analytical method; exact solutions; pseudo excitation method